Annex:

Alternate Far Detector design installation and commissioning details

1.1 Preparatory works

Before installation or the detector works can be initiated, many preparations must be conducted and boundary conditions must be met in order to allow one for both a safe as well a cost and time efficient realization of the detector installation.

Some of the most important preparation items are briefly explained in the following subchapters.

1.1.1 Construction environment underground

The existing mine and future experiment infrastructure at the 4850 ft. level must be designed to be sufficient to support the detector installation works. The requirements from detector installation works reflecting on the underground infrastructure need to be taken into account in designing the infrastructure for the experiment. Critical aspects for both the environment inside the cryostat as well around the cryostat are:

1) Safety during all the stages of realisation (escape routes in case of fire)
2) Ventilation during all stages of realisation (also smoke control in case of fire)
3) Supply routes for
    a. Construction material
    b. Components
    c. Equipment and man power
4) Other auxiliary infrastructure
5) The use of the underground infrastructure, while other activities ongoing

Especially requirements on Health and Safety should be addressed with the highest level of priority. Not only work in general is conducted in confined space in the underground environment with limited egress possibilities, also installation of the detector is another additional level of working in confined space (the cryostat) inside the underground confined space (the caverns and tunnels).

Fit out and HVAC refer to the services required within the new tunnels and caverns that allow the safe and comfortable occupation of those working within. These services necessary to conduct installation of the detector will include the followingi;

- Ventilation
- Lighting
- Water (Potable)
- Furnishing
- Waste Disposal
- Communication Network
- Power supply

All of the above are known to exist and work within the existing Mine infrastructure serving the needs of the present daily activities at the 4850 ft. level, however extending this use initially to the construction and installation activities associated will be necessary. The exact underground Fit-out requirements are still to be finalised.

1.1.2 Construction environment inside the cryostat

Necessary for the construction of the cryostat membrane components embedded inside the concrete tank it is necessary to set up a scaffolding inside for assembly and testing purposes. This scaffolding can and logically will be used for the detector installation. By doing so one enables efficient use of the scaffolding construction and also enables for safe and efficient realization of the detector installation according the demands set by the experiment as well by Health and Safety standards.

The scaffolding will be designed and realized such that it is optimally adapted to the construction sequences of the Membrane installation as to the installation sequences and demands of the detector components. See figure 1.

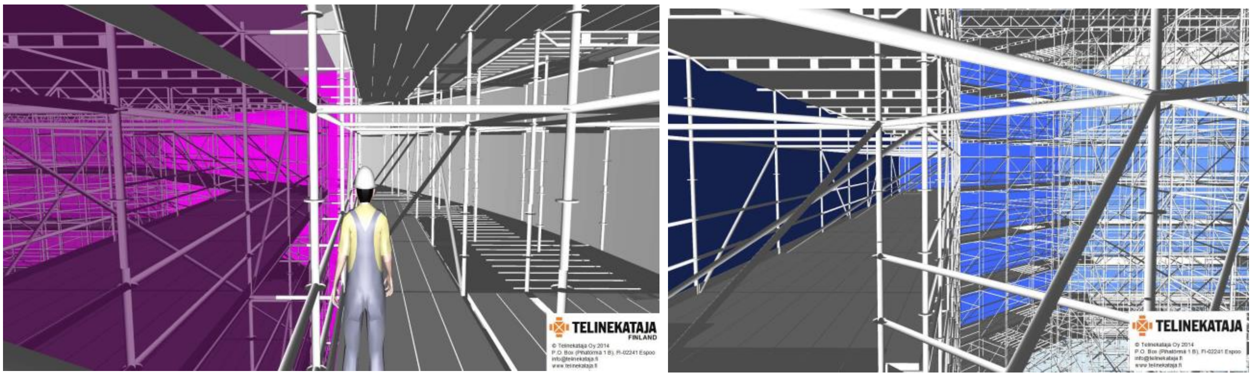


Figure 1 Scaffolding Design with in purple space left open for the Field Cage construction (courtesy Telinekataja Oy, Espoo, Finland)[ii]

Additionally the entire floor of the tank and the scaffolding systems will be fully lined with temporary wooden floor panels to protect the surfaces from damage. Where the scaffolding system support legs are required to transmit self-weight and live loads to the tank, special feet are defined together with load spreading pads[iii].

Figure 2a shows the lining of the tank floor with the temporary wooden floor panels and Figure 2b shows the bottom feet and load spreading pads which protect the membrane panel corrugations form damage.

Figure 2a Scaffolding Systems Floor Protection (courtesy Technodyne Ltd, Eastleigh, UK)
Figure 2b Scaffolding Systems Load Spreading Pads for Floor Protection (courtesy Technodyne Ltd, Eastleigh, UK)

It must be noted that the Membrane is not dimensioned to carry any loads other than the support pressure via the load spreading paths. Therefore the detector installation and scaffolding do not allow to connect anything to the membrane walls or membrane roof. Thus the detector should be completely cryostat independent.

1.1.3 Transforming cryostat interior into clean room

The Liquid Argon tank is the Main Clean Room. Access to the Main Clean Room must be protected through a Clean Room Buffer (CRB) in front of each TCO (Temporary Construction Opening in the Tank), as presented in Figure 3. Both personnel as goods (material and equipment) will pass through the Clean Room Buffer for cleaning purposes before being allowed to enter the LAr Tank Main Clean Room.

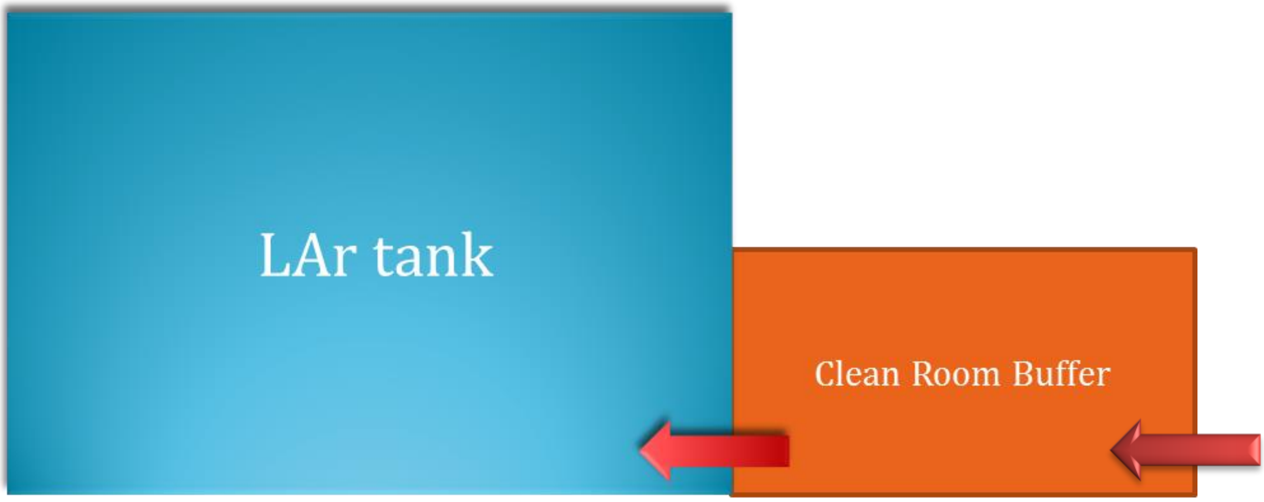


Figure 3 Schematic layout of the clean room (courtesy CERN).

Note. A CRB on top of the tank provided with access from the top into the Argon Tank is not impossible, but comparison conducted during the LAGNA-LBNO study demonstrated a top access being significantly inferior:

- Safety jeopardized for working inside the cryostat, as emergency exit from the tank and smoke and heat natural egress route are the same
- Safety challenges for work, as prevention must be taken into action from falling through the deck opening and working at great height limits free movement and efficient working
- Logistically more time consuming to bring in material and equipment and afterwards to bring out equipment
- Vertical transport costs in underground constructions around tenfold compared to horizontal transport costs (overhead crane necessary, risk prevention measures etc.)

Dimensions of the clean room buffer (for a 10kT or more sized experiment)

- Surface 16 x 10 m^2
- 5 meters high

- LAr tank access via the Clean Room Buffer
- Access dimensions from outside (services via access doors) at least 3 by 3 m^2
- Access into the tank through the TCO (temporary construction opening), size 3 by 3 m^2
- Max. 10 persons working in the area at the same time

The general concept for the Clean Room and the CRB is that air entering is filtered to exclude dust, and the air inside is constantly recirculated through high-efficiency particulate air (HEPA) and/or ultra-low penetration air (ULPA) filters to remove internally generated contaminants. Staff enter and leave through airlocks (sometimes including an air shower stage), and wear protective clothing such as face masks, gloves, boots and coveralls. Equipment inside the cleanroom is designed to generate minimal air contamination. Even specialized mops and buckets exist... Common materials such as paper, pencils, and fabrics are often excluded. Positive pressure so that air leaks out of the chamber instead of unfiltered air coming in. Determination of clean room (inner vessel = clean room, accesses through TCO's are separately to be built clean room accesses, where are material, personnel and equipment will be unpacked / cleaned before entering the clean room vessel). Size and layout of the clean room accesses to be defined, i.e. clean room process of unpacking and cleaning not to be the bottleneck in the installation process of the detector.

1.2 Detector Installation Sequences

Note: Design and Figures: courtesy Technodyne Ltd., Eastleigh, United Kingdom

1.2.1 Construction Sequences

A Construction Sequence for the double phase TPC LAr Detector installation was defined based on the use of a slightly modified scaffolding arrangement as discussed in the previous section. The proposed Construction Sequence assumes completion of the membrane and insulation system installation together with completion of all tank internal pipework and cable trays. At this stage, sections of the scaffolding will be removed and replaced by the Alimak Hek or similar climbing access platforms to provide increased functionality to the installation. On completion of the scaffolding revisions and the climbing access platform installation, the entire tank and scaffolding systems will be cleaned in preparation for the Detector installation. The proposed LAr Detector Construction Sequence consists of

Figure 4:

1) Complete installation of insulation & membrane, install cable trays from top to bottom from PMT electrical cables
2) Adjust scaffolding platforms, add Alimak-Hek platform and floor protection

Figure 5:

3) Air purge top level installation
4) Install hanging columns for detector
5) Install lowest field shaping coil to stabilise columns +

Figure 6:

5) install first top 15 levels of field shaping coils
6) Thoroughly clean top level assembly

Figure 7:

7) Install Charge Readout (CRP) from top scaffolding platform (detailed sequences described below figure 7)
8) Thoroughly clean top level assembly
9) Screen off top level to protect Anode (protective screen 1)
10) Air purge top level (allow bleed air into middle & lower levels)

Figure 8:

11) Continue installing Field shaping coils

Figure 9:

12) Complete installation of Field shaping coils
13) Thoroughly clean field shaping coils, remove protective screen (screen 1) to top level & progressively remove all scaffolding & Alimak-Hek platforms
14) Screen off field shaping coils (incl. CRO): protective screen 2
15) Air purge top & middle levels

Figure 10:

16) Construct Cathode from Modules. Cathode to be raised 300mm off tank bottom during construction
17) Thoroughly clean cathode & space used for fabrication

Figure 11:

18) Remove protective screen 2
19) Fit cathode to field cage using suitable jacks
20) Screen off entire detector: protective screen 3

Figure 12

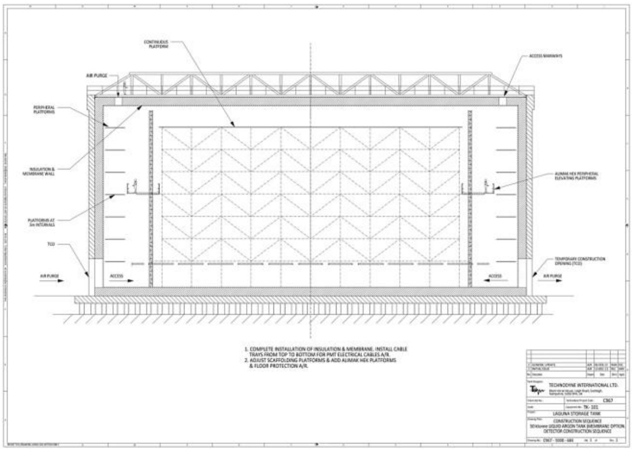
21) Remove floor protection
22) Add cable trays, junction boxes & cables for PMT's
23) Install PMT's to tank Bottom (pre-assembled L-flanges). Check out & test PMT's
24) Clean air purge bottom level

Figure 13

25) Install temporary enclosure around TCO inside & outside with air lock within the enclosure
26) Remove protective screen (screen 3) using air lock system to prevent contamination of detector
27) Close temporary construction openings

Figure 14

28) Thoroughly clean TCO areas
29) Remove temporary enclosures
30) Remove all tools, equipment etc. through tank roof
31) Exit via room manways
32) Close all tank roof openings



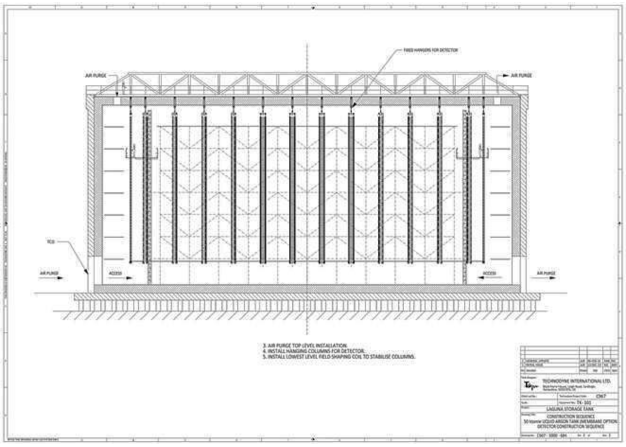
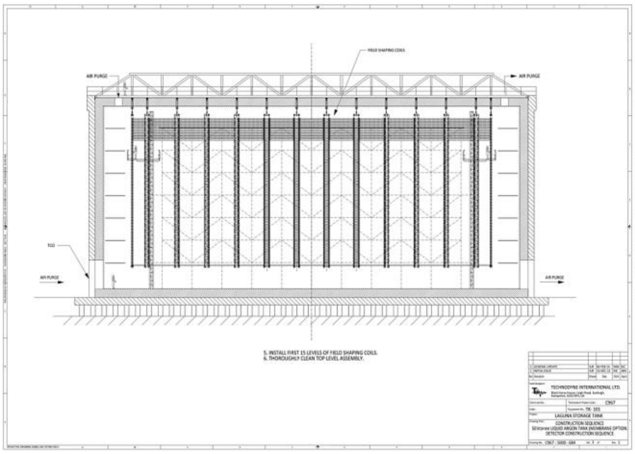


Figure 4 left LAr Detector Construction Sequences 1 + 2, courtesy Technodyne Ltd
Figure 5 right LAr Detector Construction Sequences 3…5, courtesy Technodyne Ltd



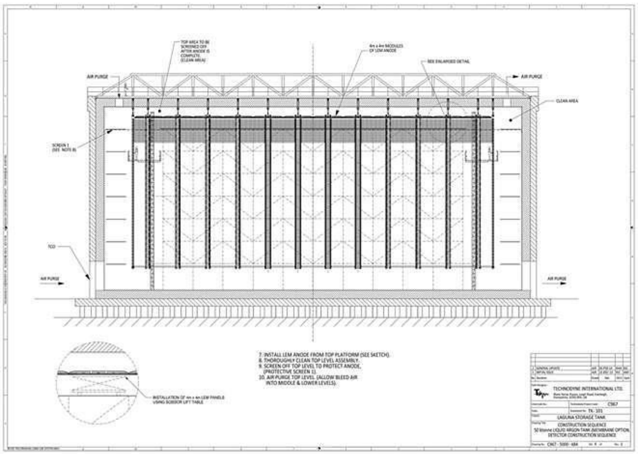


Figure 6 left LAr Detector Construction Sequences 5 + 6, courtesy Technodyne Ltd
Figure 7 right LAr Detector Construction Sequences 7…10, courtesy Technodyne Ltd

CRP sequences:

1. CRP-frame (FR4/G10)
    1. Pre-assemble off-site (e.g. 2x2 m^2)
    2. Cleaned in CRB
    3. Transported inside vessel and lifted to scaffolding deck
    4. Mounting inside (without CRP/LEM/EG)
2. Installing CRO components inside CRP-frame
    1. Pre-assembly off-site
    2. Cleaning off-site + inside CRB
    3. Transported as above
    4. Mounting inside according ordered sequence (this to have at least 2 side free to make the electronic connections from a still open frame)
3. Installing extracting grid below LEM

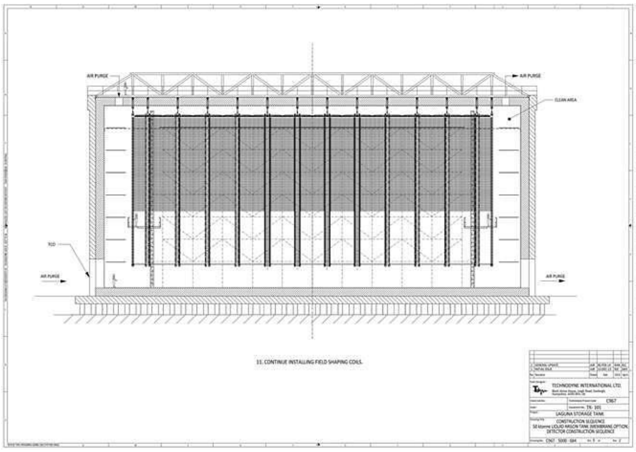
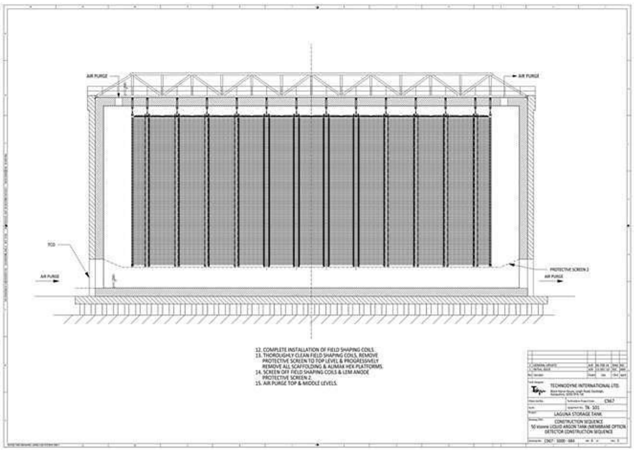



Figure 8 left LAr Detector Construction Sequences 11, courtesy Technodyne Ltd
Figure 9 right LAr Detector Construction Sequences 12…15, courtesy Technodyne Ltd

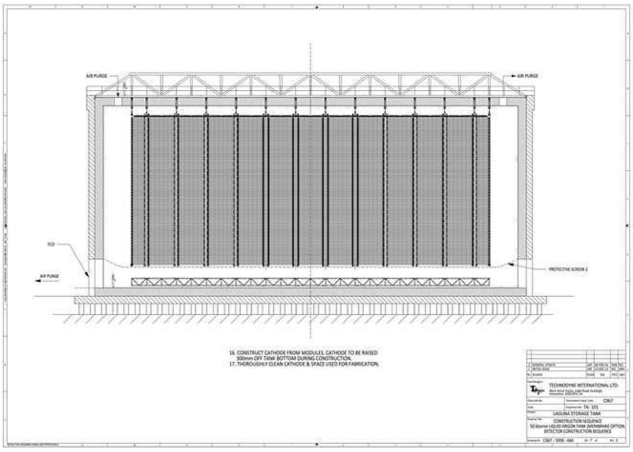
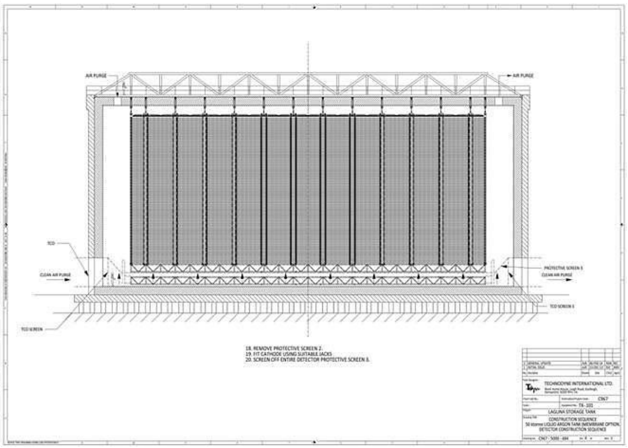



Figure 10 left LAr Detector Construction Sequences 16+17, courtesy Technodyne Ltd
Figure 11 right LAr Detector Construction Sequences 18…20, courtesy Technodyne Ltd

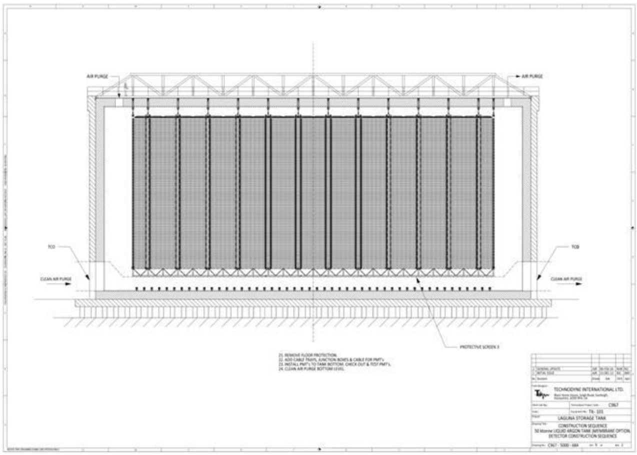
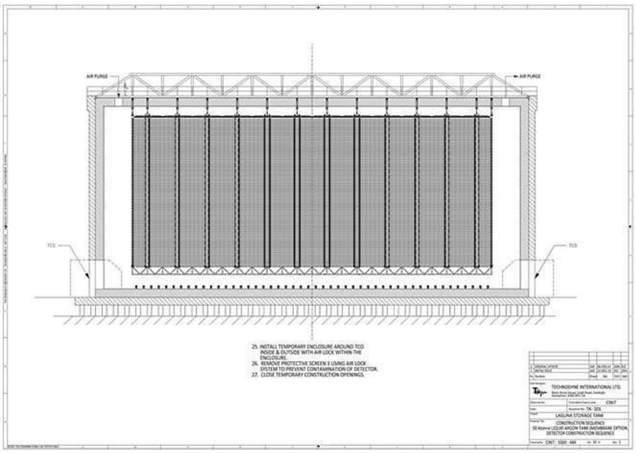



Figure 12 left LAr Detector Construction Sequences 21…24, courtesy Technodyne Ltd
Figure 13 right LAr Detector Construction Sequences 25…27, courtesy Technodyne Ltd

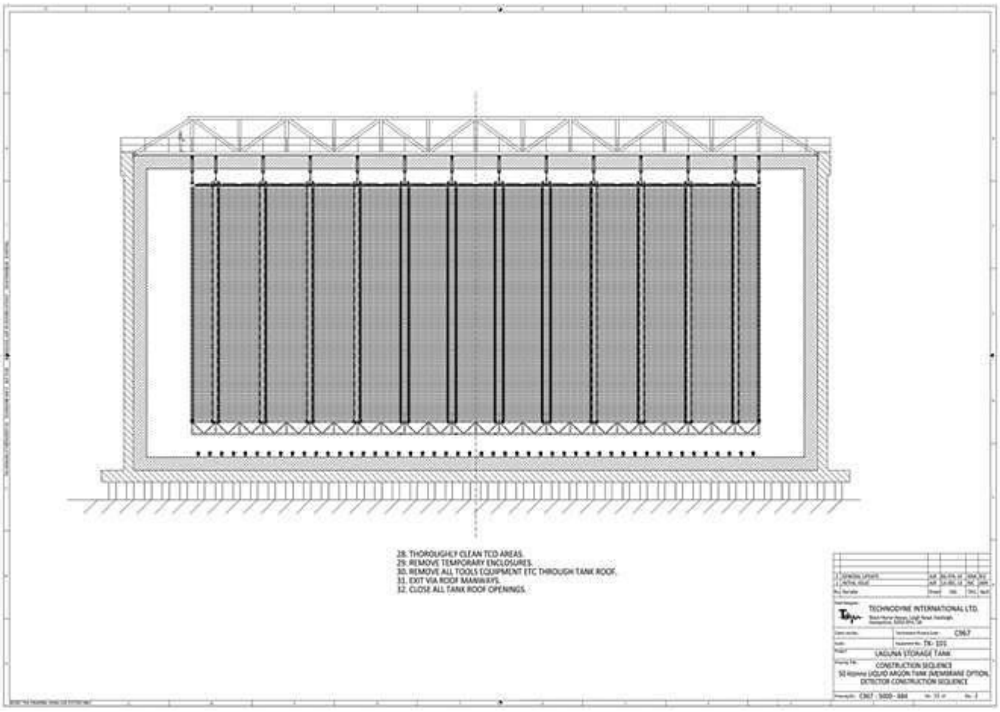


Figure 14 LAr Detector Construction Sequences 28…24, courtesy Technodyne Ltd

1.2.2 Charge readout installation

The installation of the charge readout system will be performed at the 4th step of the whole detector installation sequence as indicated in Figure 7. The installation will be performed after the handing columns and the first 15 field shaping coils are in position. The 4x4 m^2 CRP (Charge Readout Panel) will be hanged, lifted and fine-tuned from 4 ropes through the suspension feed-through located at the roof of the tank.

The 4x4 m^2 CRP consists of 64 pieces of 0.5x0.5 m^2 subunits of both the anode and LEM (Large Electron Multiplier) panels. These anode and LEM panels will be manufactured by external companies (e.g. ELTOS in Italy and Multi CB in Germany) before been brought to the experiment site. The extraction grid is formed by soldering 4m stainless steel wires to the wire soldering PCB which is later precisely positioned and tensioned to the 4x4 m^2 CRP stiffing frame.

Transporting the whole 4x4 m^2 frame and the grid is impossible to underground, thus separating and transporting the subunits will be performed. The stiffing frame is composed of external and internal reinforcement G10/FR4 bars with a length of 4m. These G10/FR4 bars will be machined, packed and transported to underground site. Figure 15 shows the subunits of the 1x1 m^2 CRP, consisting 16 FR4 reinforcement bars, 20 wire holders, 20 wire soldering PCBs soldered with 1m stainless steel wires, and 4 50x50 cm2 anode and LEM panels. The 4x4 m^2 CRP has a similar structure and all its subunits will be packed and transported underground where the assembling will be performed. Figure 16 shows a detailed sequence to assemble the 1x1 CRP, which is to be applied to the assembling of the 4x4 m^2 CRP as well.

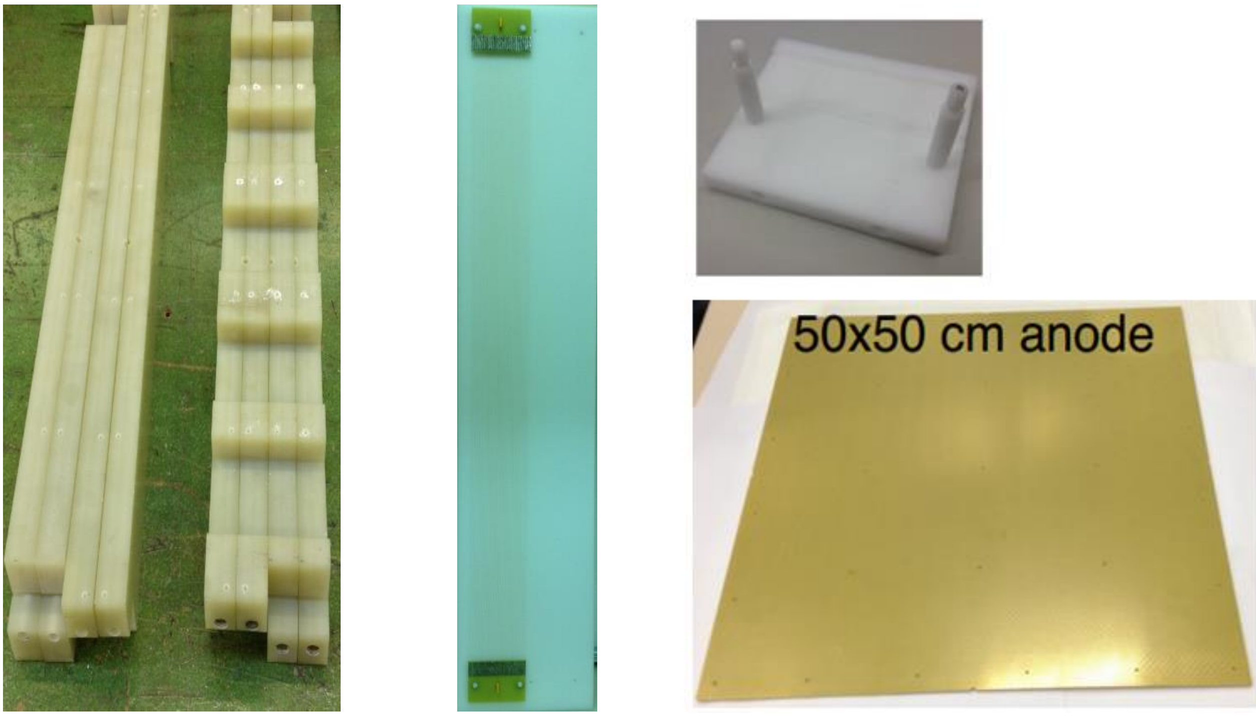
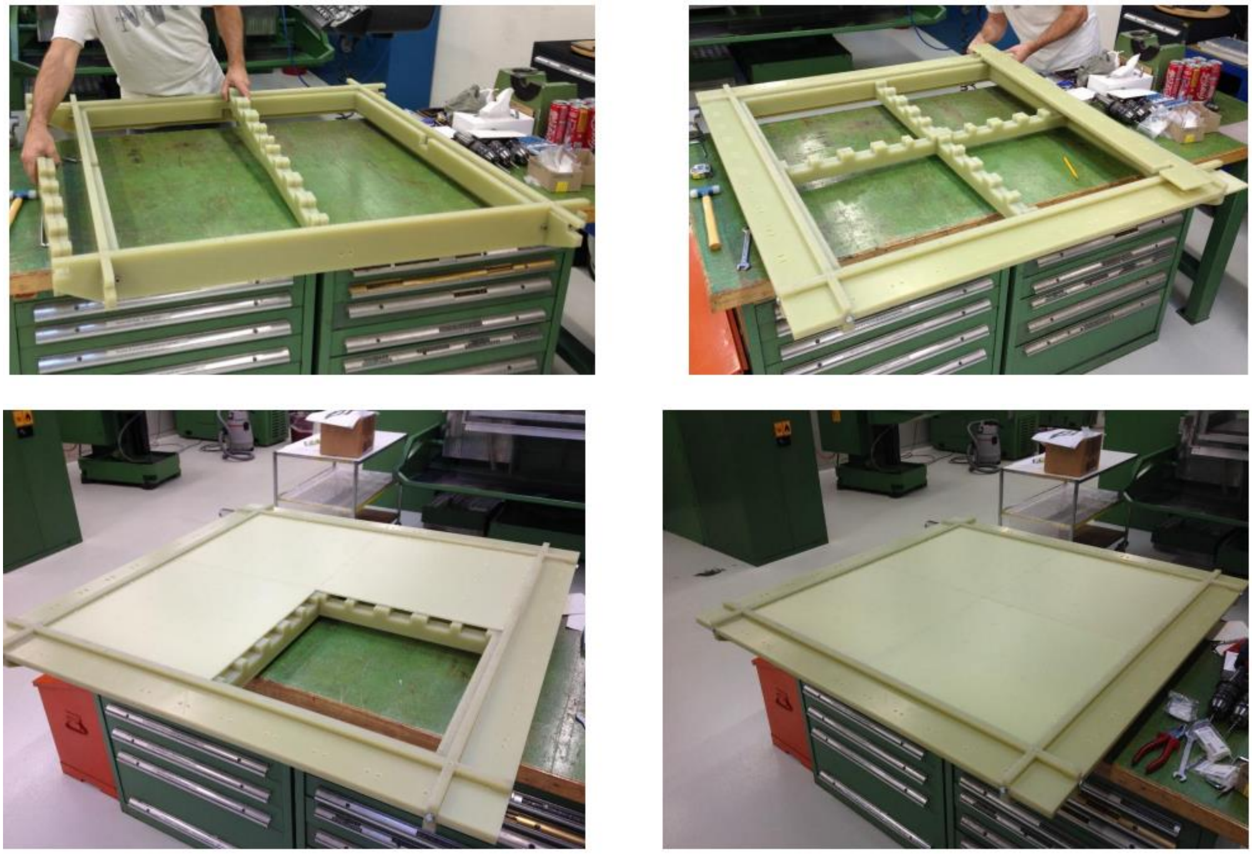


Figure 15 Subunits to be assembled into the 1x1 m^2 CRP. Left: FR4 reinforcement bars, including both the internal and external ones; middle: the 32 wire soldering PCBs together with the 1m wire soldered; right: the wire holder and the 50x50 cm^2 anode (the LEM has the same dimension as the anode). Courtesy ETH Zürich



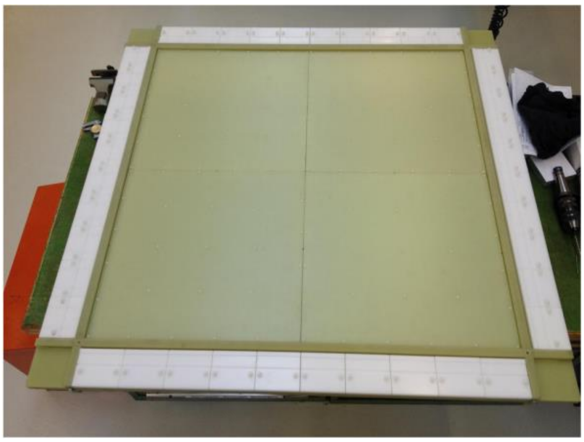
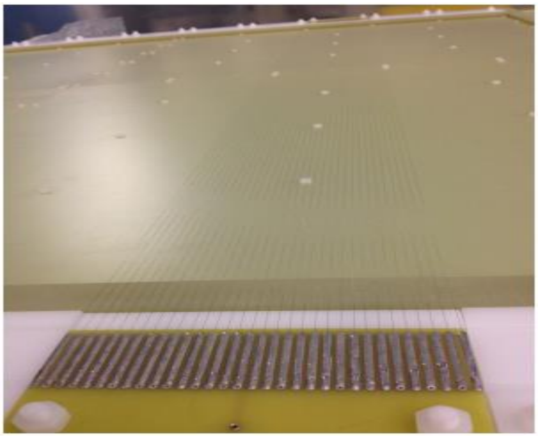
 

Figure 16 Assembling sequence of the 1x1 m^2 CRP. From left to right, top to bottom: assembling of the internal reinforcement bars; assembling of the external reinforcement bards; installation of the LEM; installation of the anode; installation of the wire holders; installation of the 1 m extraction wire. (The LEM and anode are shown with fake FR4 sheets without printed circuit). Courtesy ETH Zürich

After the whole 4x4 m^2 CRP has been assembled underground, they'll be lifted and precisely adjusted with 4 stainless steel ropes through the suspension feed-through. The lifting and adjustment will be performed independently for each 4x4 m^2 CRP.

The Charge Readout/Anode panels will be transported to the top level of the scaffolding using the scaffolding lift. The top level scaffolding floor will be sealed off using Screen 1 (shown red in Figure 17) in preparation for Anode assembly and will be designated a clean room area with in/out purging air flow each side of the screen. Field Shaping Coil and Anode assembly activities will be separated by the screen and can therefore run concurrently. The panels will be assembled and installed once the Hanging Columns and the top 15 Field Shaping Coils have been constructed. It is proposed that an elevating table/scissor lift arrangement will be used to join the charge readout planes together and act as a platform for system checkout. The completed 4m x 4m panels will then be raised into position for attachment to the ribbon cables of the instrumentation feed-throughs and connection to the suspension systems. Figure 17 and 18 show an extract from the double phase TPC LAr Detector Construction Sequence and the proposed arrangements for the lifting of the Charge Readout/Anode panels.

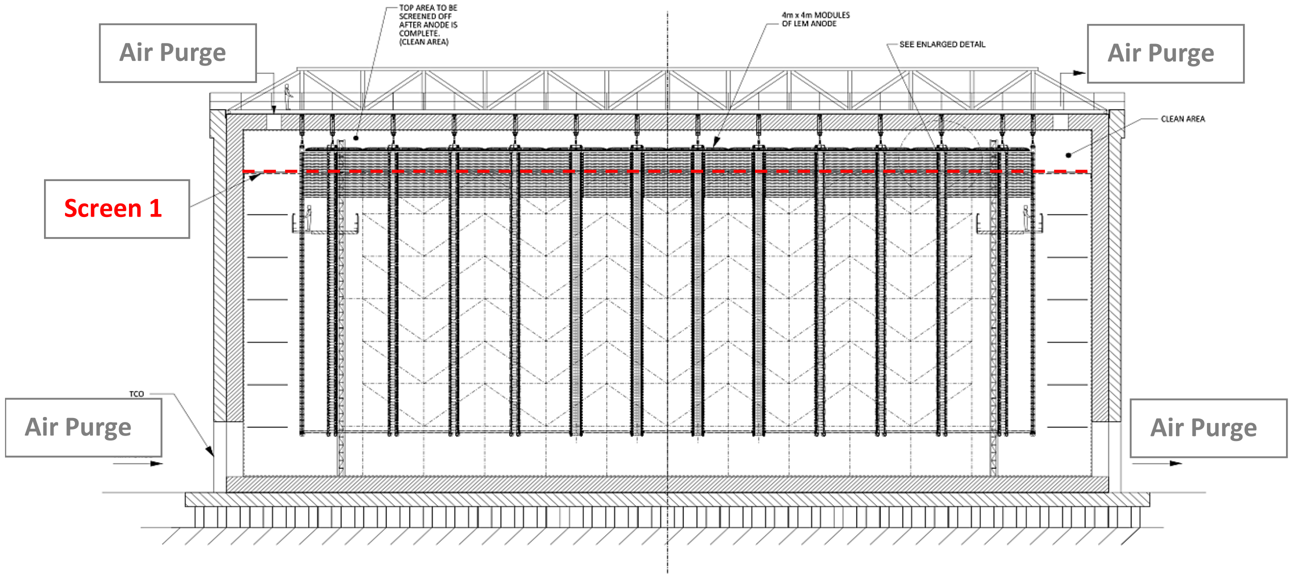


Figure 17 Extract from the LAr Detector Construction Sequence. Courtesy Technodyne Ltd.

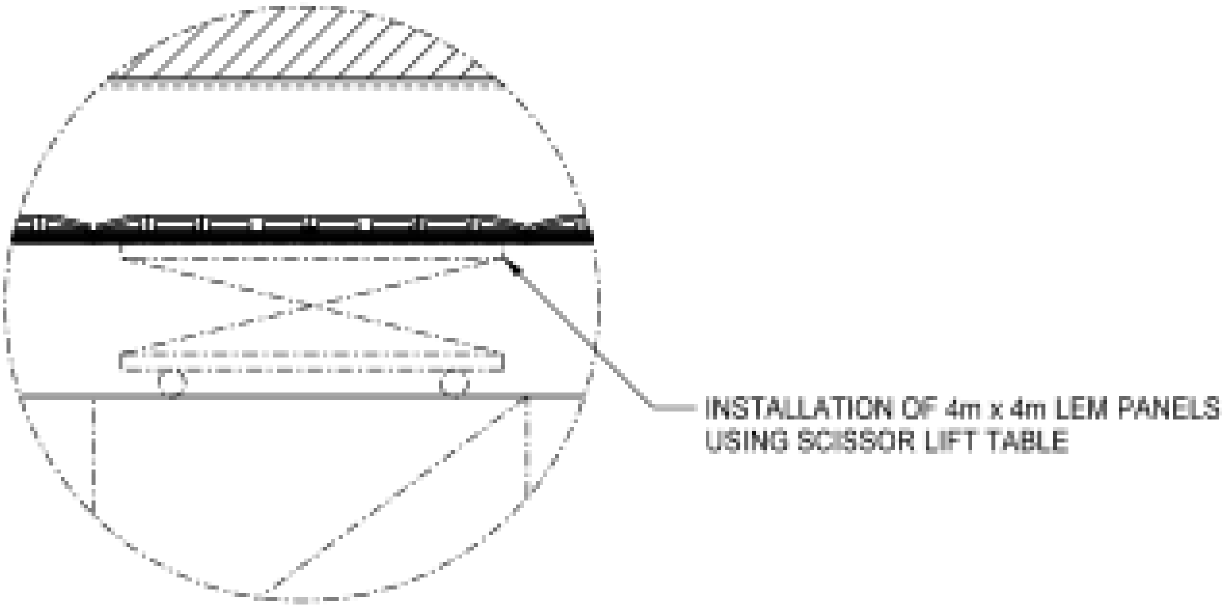


Figure 18 Proposed arrangement for the lifting of the CRP Panels. Courtesy Technodyne Ltd

1.2.3 Installation of Field Cage Hanging Columns

The Field Cage Hanging Columns will be the first components of the Detector to be installed. Installation will commence with the attachment of the Special Hanging Support System to the underside of the LAr Membrane Tank Deck Structure through the insulation sleeves in multiple locations. Once attached, the flanged bellows unit will be fitted to each insulation sleeve and the bottom clevis heights of each support will be adjusted using the threaded turnbuckles to achieve a common datum level. Figure 19 shows the installation of the Special Hanging Support System.

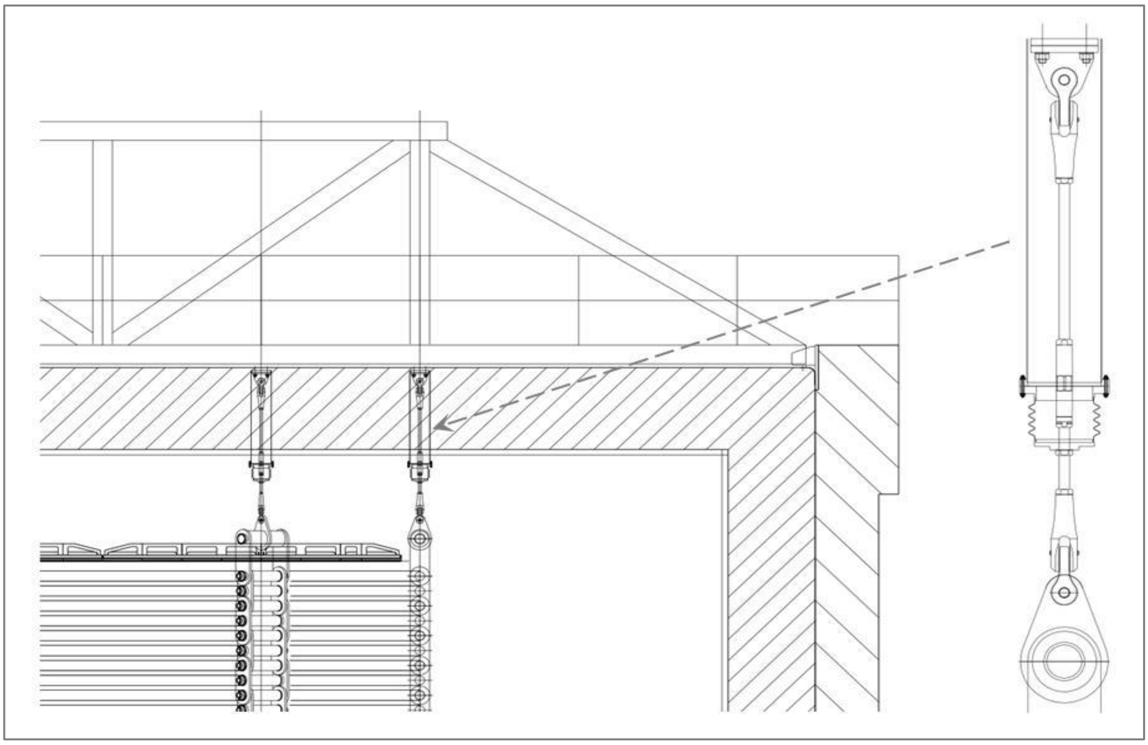


Figure 19 Installation of the Special Hanging Support System (courtesy Technodyne)

Once the Special Hanging Support System has been installed, the Hanging Columns will be attached to the free end clevis of each supports. The proposed design allows the Hanging Columns (each 1559 kg mass) to be installed in three possible ways:

- Fully assembled off site and brought to site folded, then lifted into place as a complete assembly
- Assembled below ground from pre-assembled sections, then lifted into place as a complete assembly
- Assembled in sections at height from the Alimak Hek climbing access platforms

Figure 20 shows an exploded view of a single Hanging Column including the composite G-10CR links and the machined stainless steel pins. The Hanging Column is also shown attached to the Special Hanging Support System and also as a complete assembly.

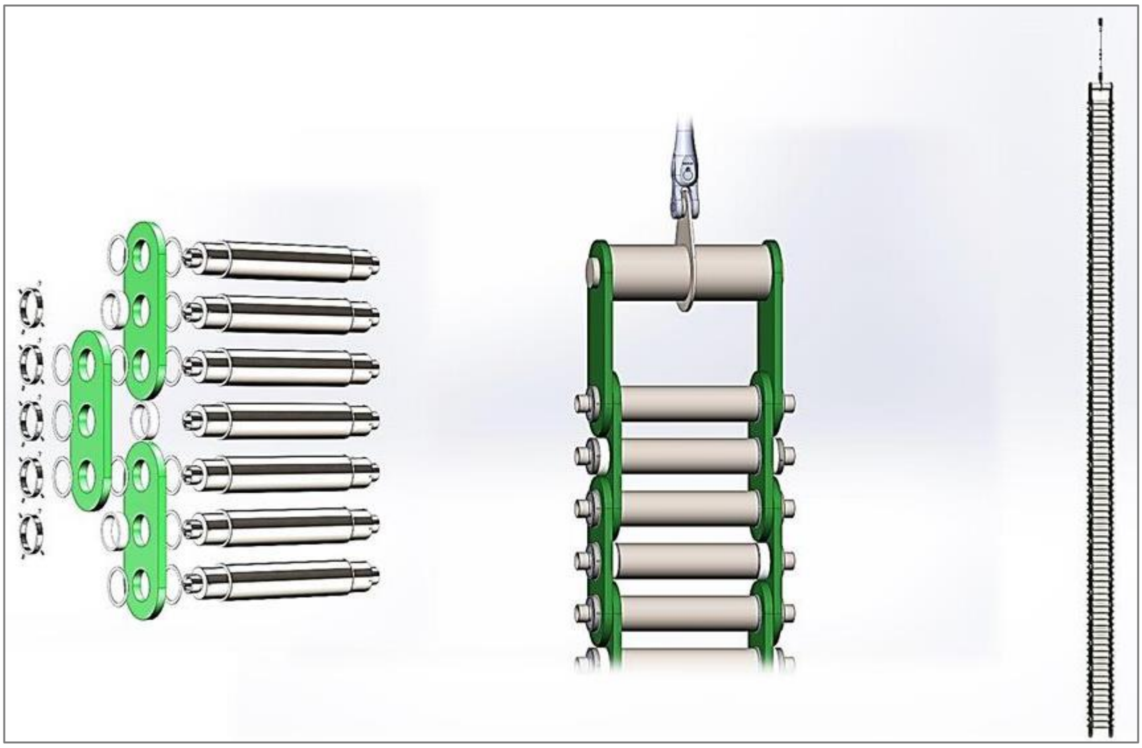


Figure 20 Exploded & Assembled Views of a Hanging Column. Courtesy Technodyne Ltd

It is important that all hanging columns are of equal length. Dimensional tolerance limits on G-10CR Links may not guarantee sufficient accuracy due to the number of parts involved, particularly where machining is likely to be done in batches. As discussed previously in Section 4, it is recommended that the machine shop selected for manufacture of the G-10CR links is also responsible for the assembly and final accuracy of the complete Hanging Columns. It is also recommended that the assembled columns should be inspected at the supplier's works prior to despatch to ensure consistency of manufacture.

If it is decided to install the Hanging Columns in sections, this approach can still be achieved by inspection of full length trial-fit columns. After acceptance, the sections would be tagged for matched assembly on site.

1.2.4 Installation of Field Shaping Coils

The proposed Field Cage design is based on the use of Hanging 'Chain Type' Columns with integrated 'pins' and longer/corner sections of Field Shaping Coils, fixed between the Hanging Columns to form a complete Field Cage.

It is proposed that the Field Shaping Coils should be installed from the top down. A single Field Shaping Coil will be fitted to the bottom of the Hanging Columns to stabilise the installation. The Alimak Hek platforms will be fitted with installation tooling and assembly aids as necessary to create safe and convenient work stations for the installation crew and will also be used to raise materials to the required working level. Figure 21 shows the proposed Field Cage concept of Hanging 'Chain Type' Columns with infill straight/corner sections of Field Shaping Coils being installed top down from the Alimak Hek platforms.

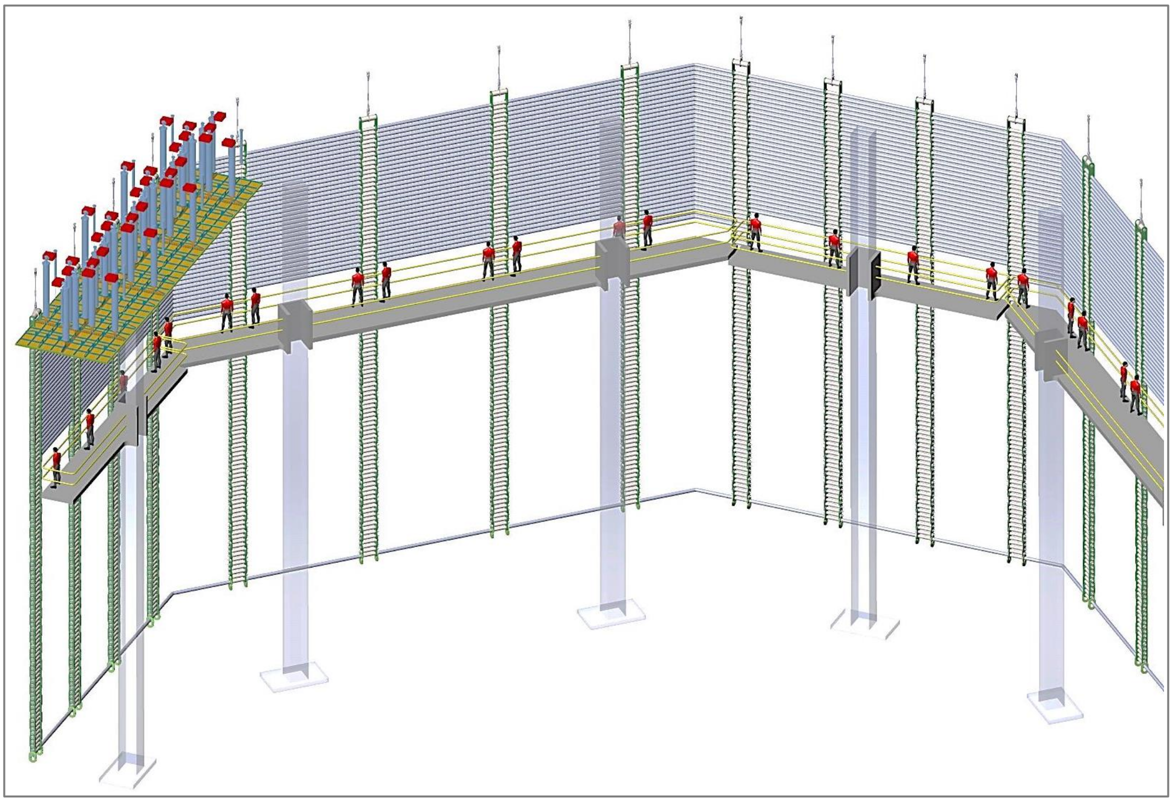
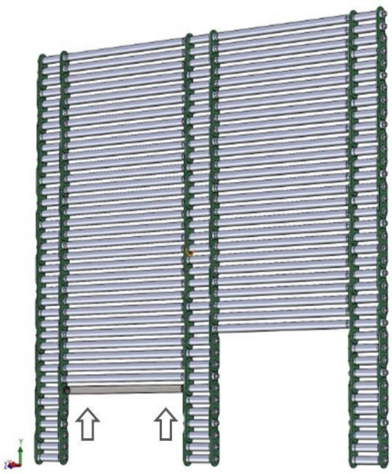


Figure 21 Field Cage Concept of Hanging ‘Chain Type’ Columns with Infill Field Shaping Coils. Courtesy Technodyne Ltd

In order to maintain consistent installation on each Field Shaping Coil and to avoid the possibility of cumulative tolerance build up it is proposed that the corner shaping coil tubes should be fitted face-to-face with the Hanging Column pins (i.e. with no gap). The straight tubes will be clamped in place using the split clamp and 2 off M12 socket head cap screws leaving a pre-set gap with tolerance to allow for any small tolerance differences. Figures 22, 23 and 24 show the installation of the straight and corner infill Field Shaping Coil sections.



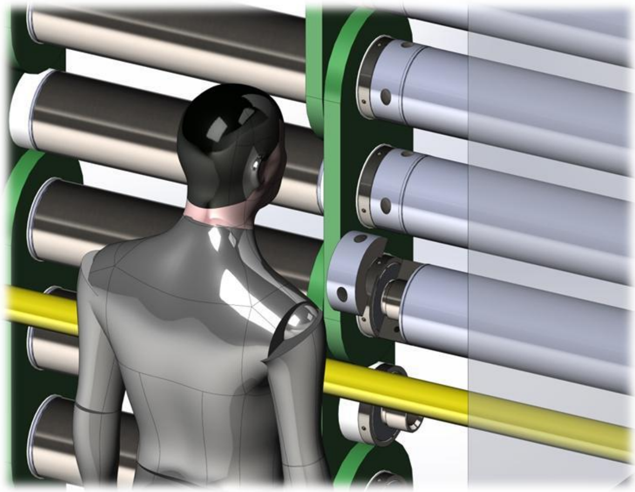


Figure 22 Installation of Straight Infill Field Shaping Coils. Courtesy Technodyne Ltd

Figure 23 Installation of Straight Infill Field Shaping Coils using Split Clamp. Courtesy Technodyne Ltd

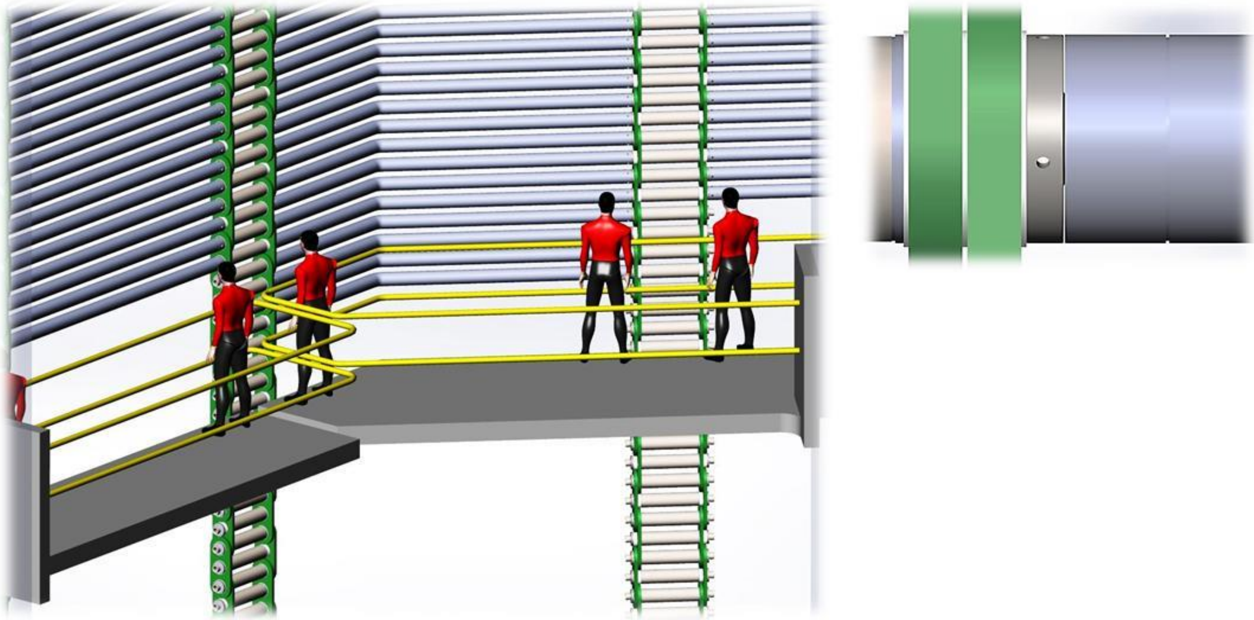


Figure 24 Installation of Corner Infill Field Shaping Coils. Courtesy Technodyne Ltd

Once the installation of all the Field Shaping Coils is complete, all the Field Cage components will be thoroughly cleaned using the scaffolding and the Alimak Hek platforms for all-round access. It will also be advantageous to thoroughly clean the access platforms at the same time in order to reduce the possibility of contamination at the next stage of the Detector installation. Once all cleaning is complete, the Screen 1 will be removed from the top level; all scaffolding/Alimak Hek platforms will be gradually dismantled and removed from the tank via the TCOs. A second protective Screen 2 (shown red in Figure 25) will be installed beneath the completed Field Cage to isolate the upper and middle sections of the Detector from follow-on work on the Cathode installation below. Both the upper and the lower levels of the tank will continue to be air purged to maintain cleanliness levels in each area of the installation. Figure 25 shows the completion of the Field Cage and the installation of the new Screen 2. Figure 26 shows an internal 3D Model view looking outward from within the Field Cage.

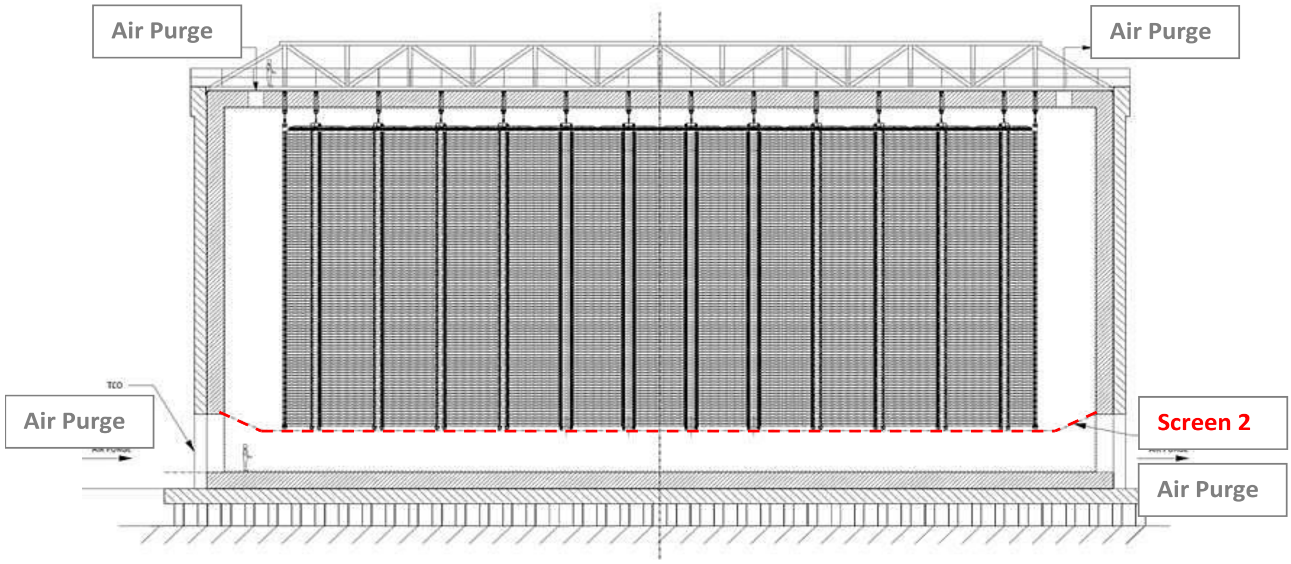


Figure 25 Completion of the Field Cage and the Installation of the New Screen 2. Courtesy Technodyne Ltd

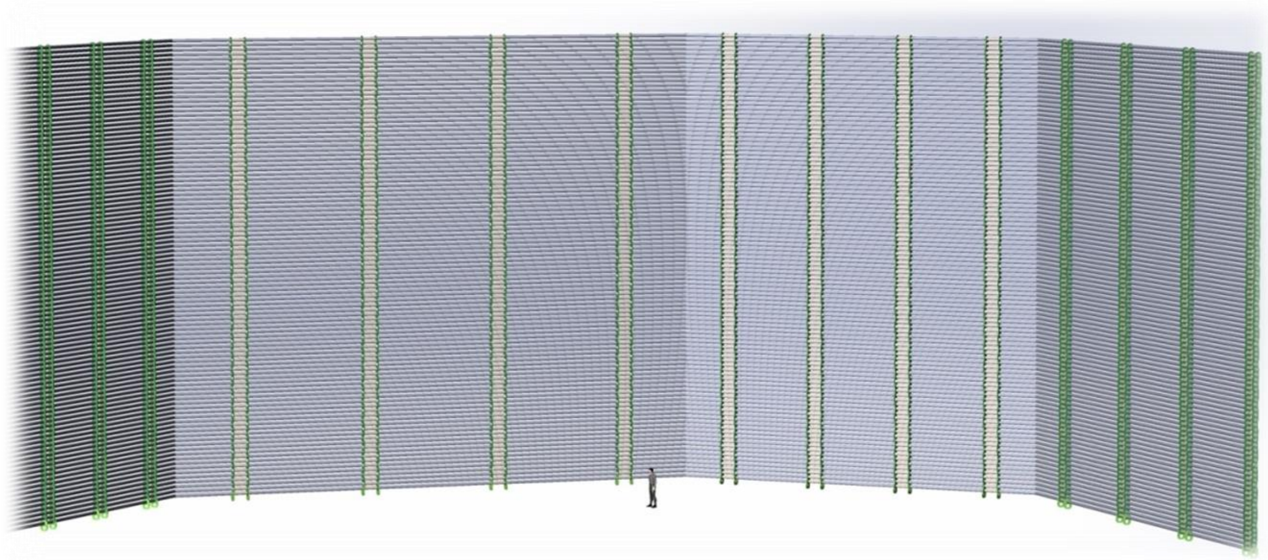


Figure 26 Internal 3D Model View looking outward from within the Field Cage. Courtesy Technodyne Ltd

1.2.5 Installation of Cathode

A fundamental part of the Cathode development and design process involved the consideration of how the Cathode structure could be manufactured, transported to site, transported to the cavern through the restricted decline access at the Pyhäsalmi site and then constructed in a 'Clean Room' environment inside the completed Membrane Tank. This requirement presented considerable challenges in terms of logistics and the development of the overall concept for fabrication. It was concluded that a Modular Construction approach would be required in order to maximise off-site shop fabrication and minimise on-site assembly. This approach was also considered essential in order to ensure the cleanliness of construction and to minimise the installation timeline.

The maximum module size proposed will be the 6m Module comprising 3 full 2m x 2m x 1m deep bays of the Cathode structure. This module will therefore be 6m x 2m x 1m deep and will fit within the defined decline access limits. All specialist node preparation and welding of the modules will be carried out under controlled fabrication shop facilities so the installation work within the LAr Membrane Tank will comprise the setting out, assembly, welding and final cleaning the of the Modules.

High levels of Quality Control will be possible with the Modular Construction concept and following fabrication shop inspection, each module will be cleaned to ISO 8 cleanliness standard and double wrapped prior to despatch and transportation to site. When required, the Modules will be unpacked and transferred to the LAr Membrane Tank beneath the previously constructed Field Cage in a pre-defined sequence to allow the main Peripheral and Inner Structure Modules to be set out.

It is anticipated that the Cathode will be set out with all Modules raised 300mm above the floor protection at the base of the tank using portable trestles and staging. This will allow access to the lower tube sections and provide space for alignment, assembly and inspection equipment. It is proposed to use a series of enclosed or open orbital welding heads to assemble the Modules.

Suppliers of such equipment were contacted and quotations received for the necessary standard off-the-shelf hardware and consumables specifically selected for the specified tube sizes and wall thicknesses. For typical details of orbital welding equipment see http://www.orbitalum.com. All joints between Modules will be shop prepared, each weld will be shielded & cleaned on completion so the whole assembly process will be as clean as possible, and also bearing in mind that the airflow through the assembly area will be controlled by purging and the space above Screen 2 will also be purged separately to maintain cleanliness levels.

Details of the Orbitalum Enclosed and Open Orbital Welding Heads together with a 3D illustration of the proposed assembly technique is shown in Figure 27. These devices are clipped round adjacent tube sections, providing control of the weld gap and location, then an automatic weld head provides a shielded and controlled fully automatic weld around the joint. Figure 28 shows how the automatic orbital welding techniques will be utilised for the assembly of the Cathode Modules.

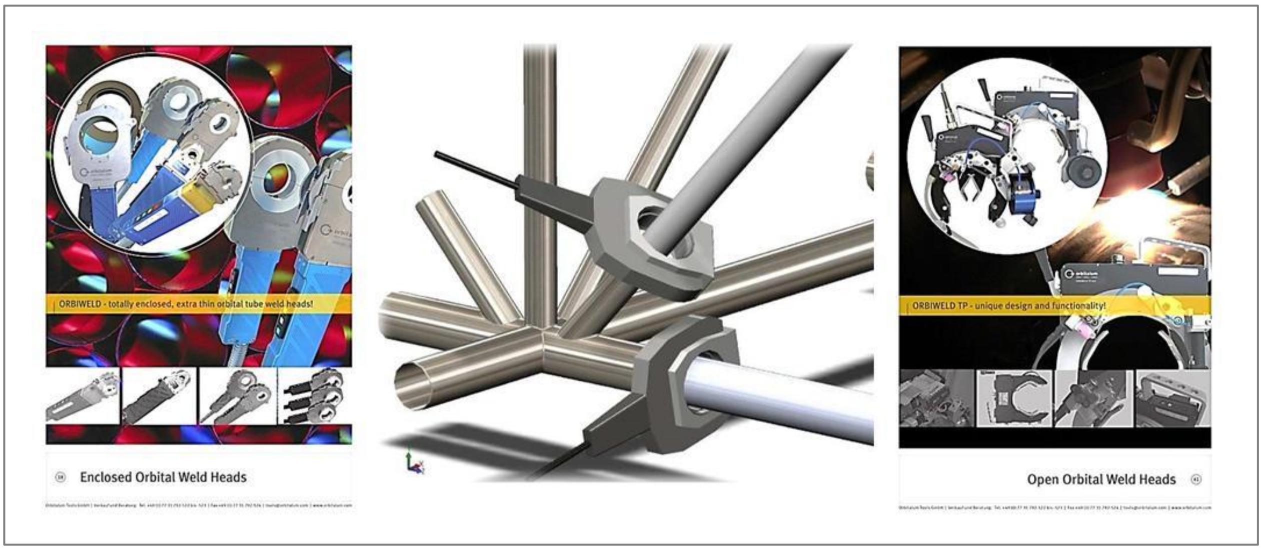


Figure 27 Details of Automatic Orbital Welding Equipment. Courtesy Technodyne Ltd + Rhyal Eng. Ltd.

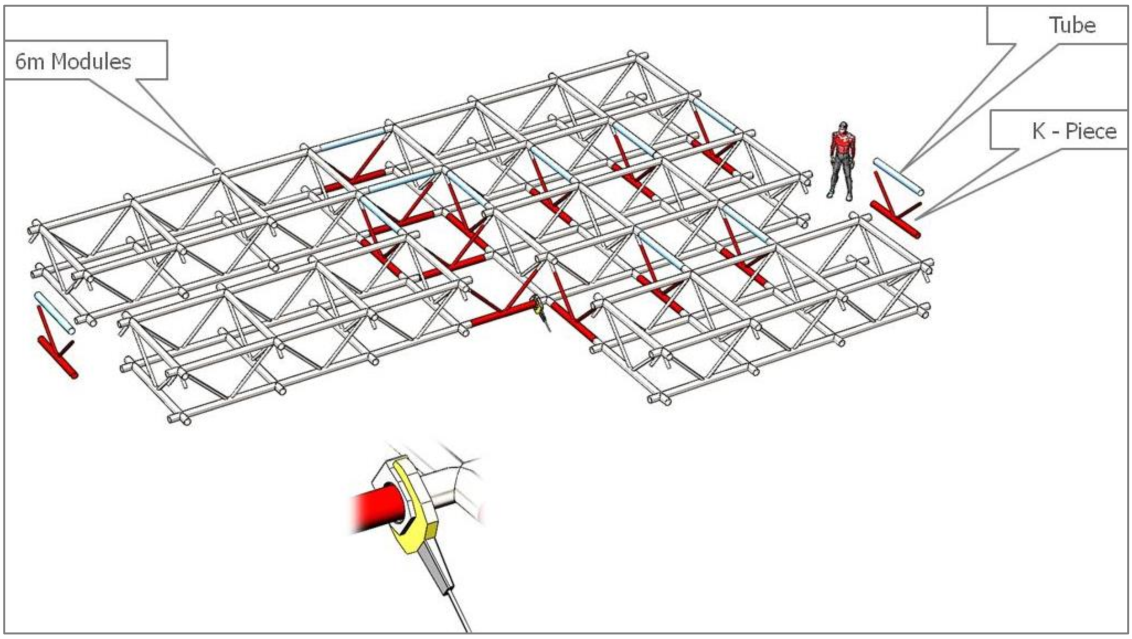


Figure 28 Proposed Use of Automatic Orbital Welding Equipment. Courtesy Technodyne Ltd

Following completion of the structural Cathode module assembly, the off grid modules will be installed in alternate orientations as requested by the Scientific Partners. It is suggested that this task should be carried out at the end of the Cathode assembly in order to protect these items from possible construction damage. Figure 29 shows typical grid modules

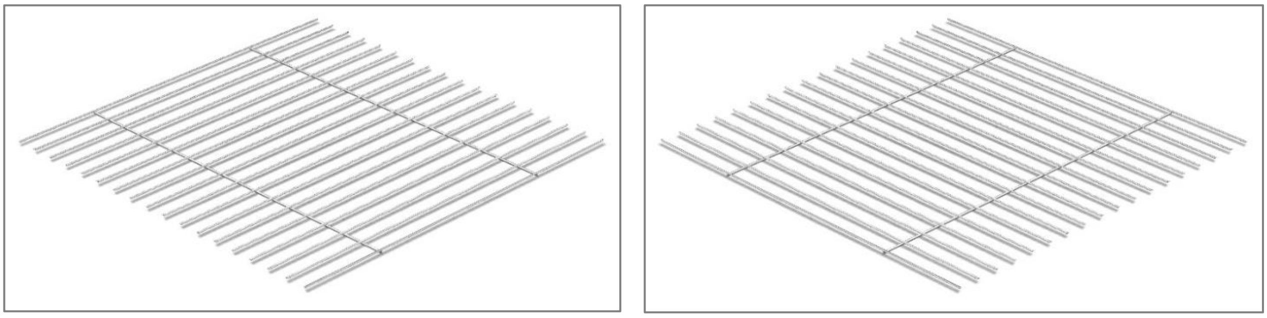


Figure 29 Typical Grid Modules. Courtesy Technodyne Ltd. + ETH Zürich

Having installed all the grid modules, the entire Cathode assembly will be cleaned in preparation for lifting and attachment to the Field Cage. It is anticipated that the cleaning task will be minimal since a high degree of cleanliness will have been followed throughout the installation. However, it is inevitable that some cleaning will be required and this should be carried out thoroughly prior to the installation of suitable jacking equipment around the Cathode periphery. Such equipment is typically used in the construction of LNG storage tank shells where the entire tank is jacked vertically to allow new shell courses to be installed.

Once the jacks are in place and conditions within the construction area have settled, the second protective Screen 2 will be removed to allow Cathode assembly to be jacked into place beneath the Field Cage. Once jacked and installed in position using the split G-10CR links and composite bolts as shown in Figure 30, the Cathode will be surveyed to check the central deflection (sag). Later, when the tank is cooled and filled with LAr, the sag will be checked again by means of the Servo Level Gauges installed at roof level.

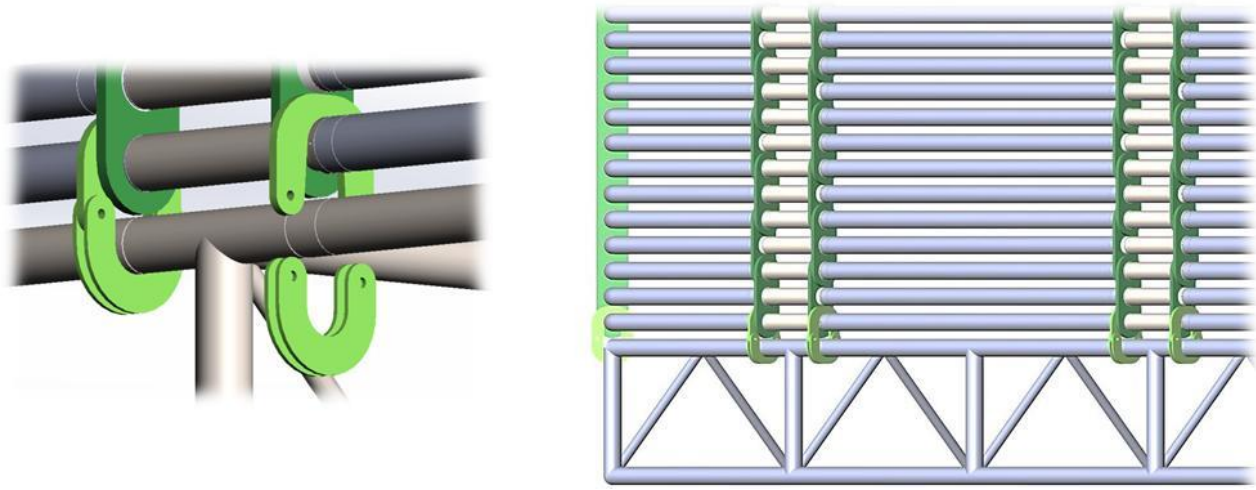


Figure 30 Connection of the Cathode to the Field Cage using Split Links. Courtesy Technodyne Ltd.

Once the Cathode installation is complete and the inspection/deflection checks carried out, a third protective Screen 3 (shown red in Figure 31) will be installed beneath the completed Field Cage and Cathode to isolate the upper and middle sections of the Detector from follow-on work on the PMT installation below. Both the upper and the lower levels of the tank will continue to be air purged to maintain cleanliness levels in each area of the installation.

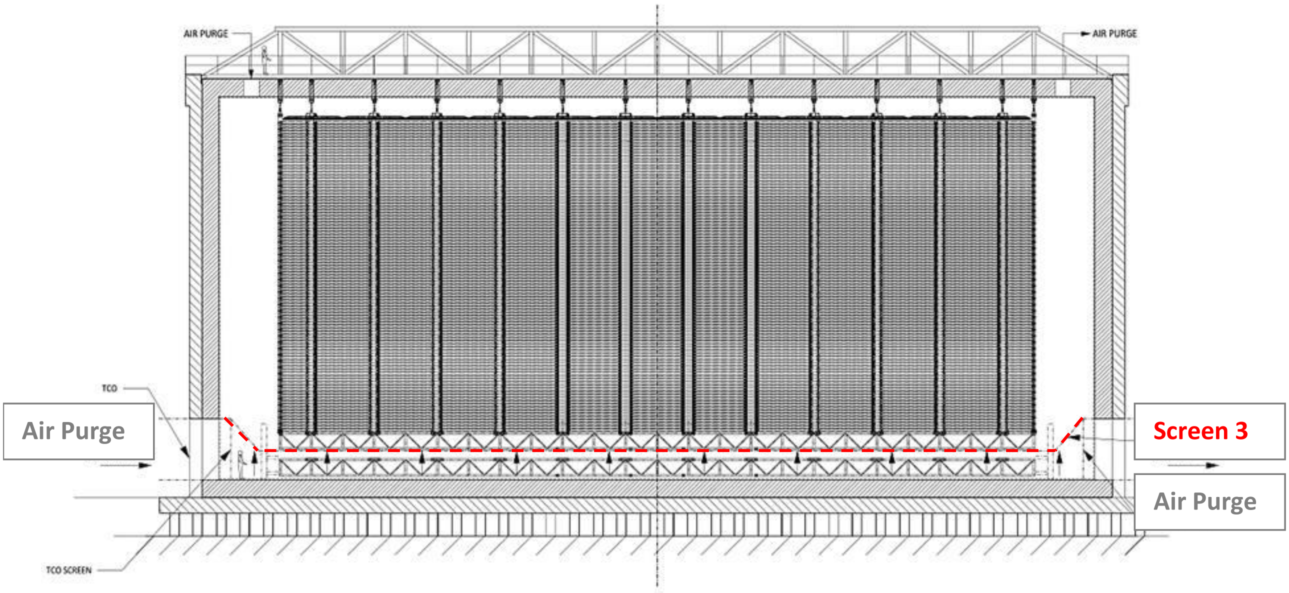


Figure 31 Completion of the Cathode and the Installation of the New Screen 3. Courtesy Technodyne Ltd.

1.2.6 Installation of Light Readout / PMTs

The LAr Membrane Tank lower membrane panels will be provided with local stiffening plates for the attachment of brackets to support the Light Readout Photo Multiplier Tubes (PMTs). The PMTs will be located on a 1m x 1m grid pattern beneath the Cathode, offset from the Cathode tube centrelines by 0.5m so that there is a clear and direct field of view through the Cathode.

Each PMT mounting bracket will incorporate attachment points for cable trays to be clipped/bolted into place to allow PMT wiring to be connected to the existing wiring within the tank. All connections will be checked for continuity right through to the cable feed-throughs and the instrumentation systems outside. The detailed support of the PMT by ETHZ is shown in Figure 32.

Throughout the PMT installation, the Membrane Tank will be continuously air purged above and below the protective Screen 3 in order to maintain cleanliness levels of the installed Detector component parts in each area. Figure 33 shows the completed installation of the PMTs beneath the Cathode.

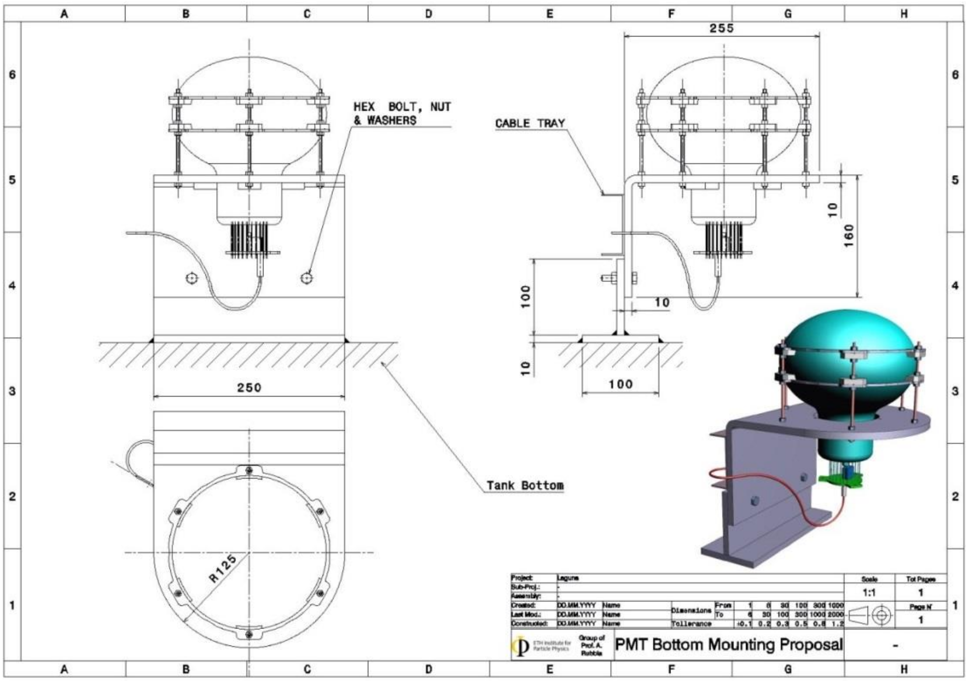


Figure 32 PMT Mounting Arrangements for the Membrane Tank. Courtesy ETH Zürich.

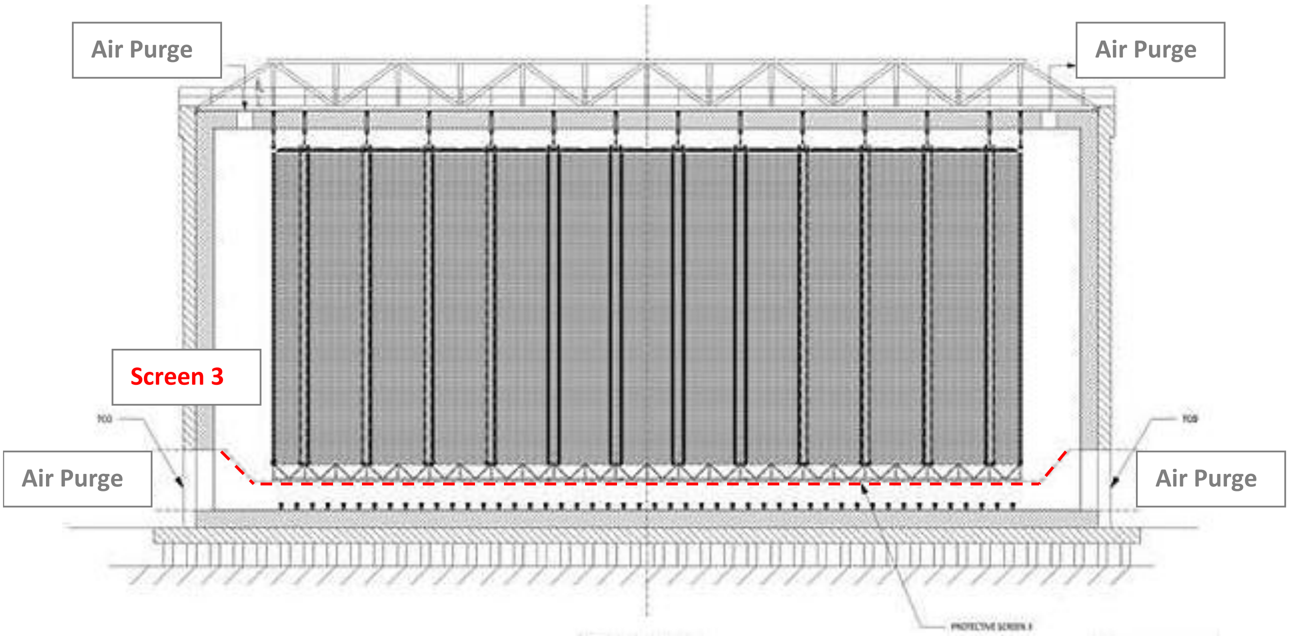


Figure 33 Completion of the PMT Installation beneath the Cathode. Courtesy Technodyne Ltd.

1.3 FINALIZATION BEFORE COMMISSIONING

1.3.1 Closing of Tank

Once the Detector installation is complete and all instrumentation systems thoroughly checked out, all installation equipment will be removed from the Membrane Tank via the TCOs, prior to closure of the tank walls and completion of the insulation/membrane installation. For the special cleanliness requirements associated with the LAr Detector and Instrumentation, it will be necessary to install temporary Enclosures and Airlocks around the inside and outside of each TCO (shown red in Figure 34).

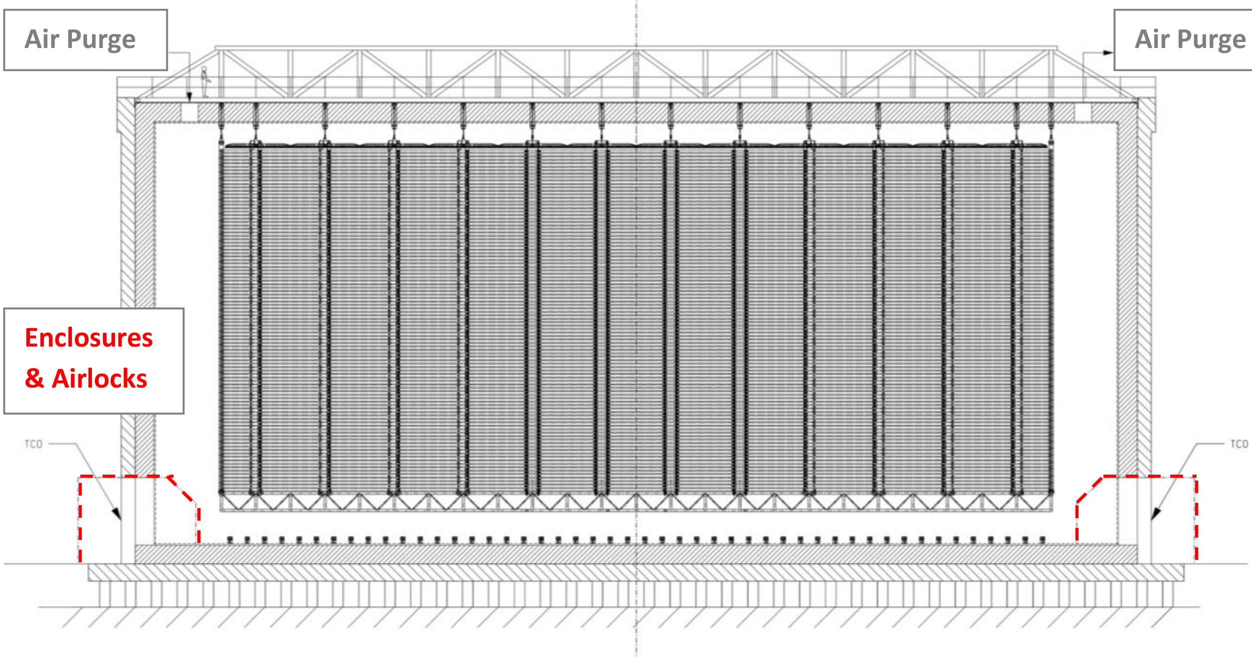


Figure 34 Installation of Temporary Enclosures & Airlocks around TCOs. Courtesy Technodyne Ltd.

At this stage it will be possible to remove the Protective Screen 3, using the air lock system to prevent contamination of the Detector. The Membrane Tank and Detector area will be continuously air purged to maintain cleanliness levels of the installed Detector.

Once the Enclosures and Airlocks are in place, the TCOs will be sealed using established techniques. Reference Section 4 of this Report, Figure 35 shows the insulation and membrane panel arrangement around the TCO, Figure 36 shows the TCO closure plate installation and Figure 37 shows the arrangement for external formwork, reinforcement and concreting.

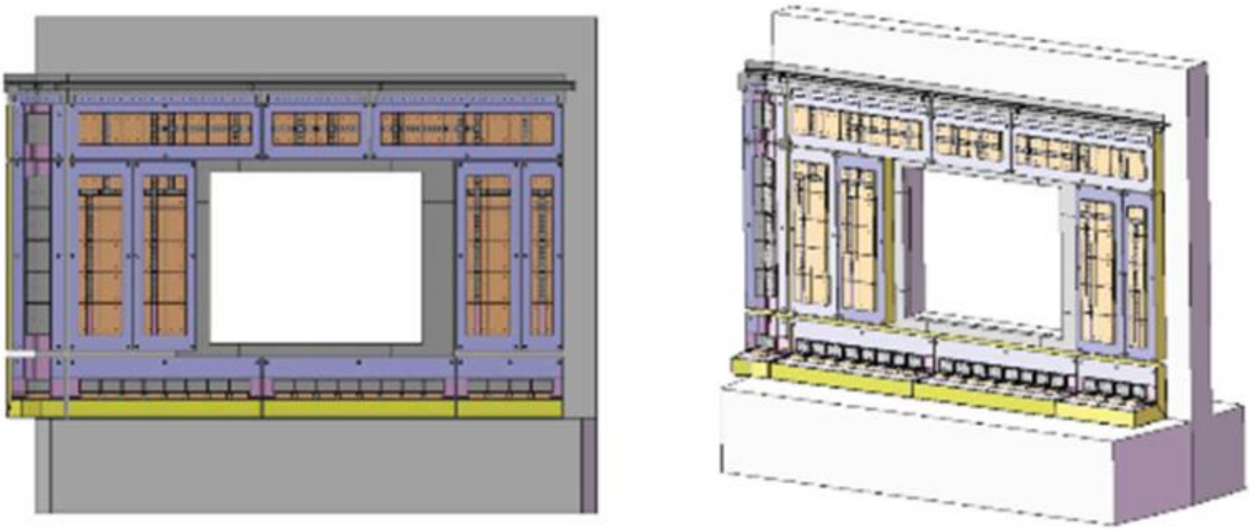


Figure 35 Insulation & Membrane Panels around TCO. Courtesy Techodyne Ltd.

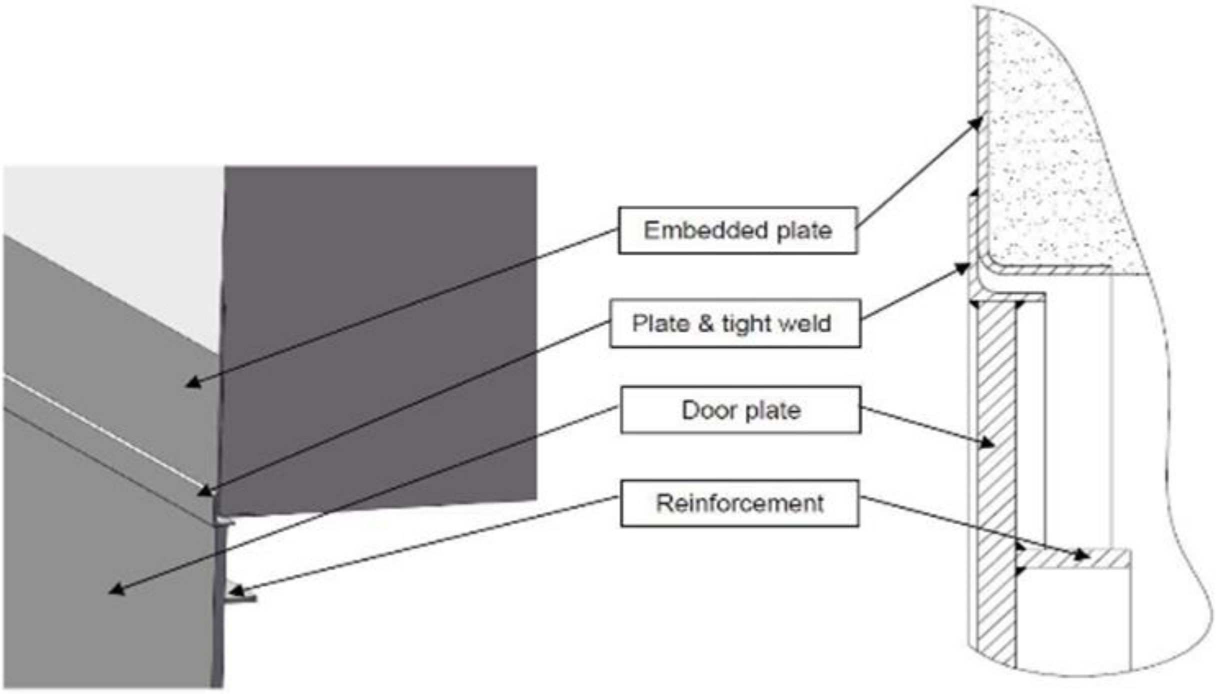


Figure 36 TCO Closure Plate Installation. Courtesy Technodyne Ltd.

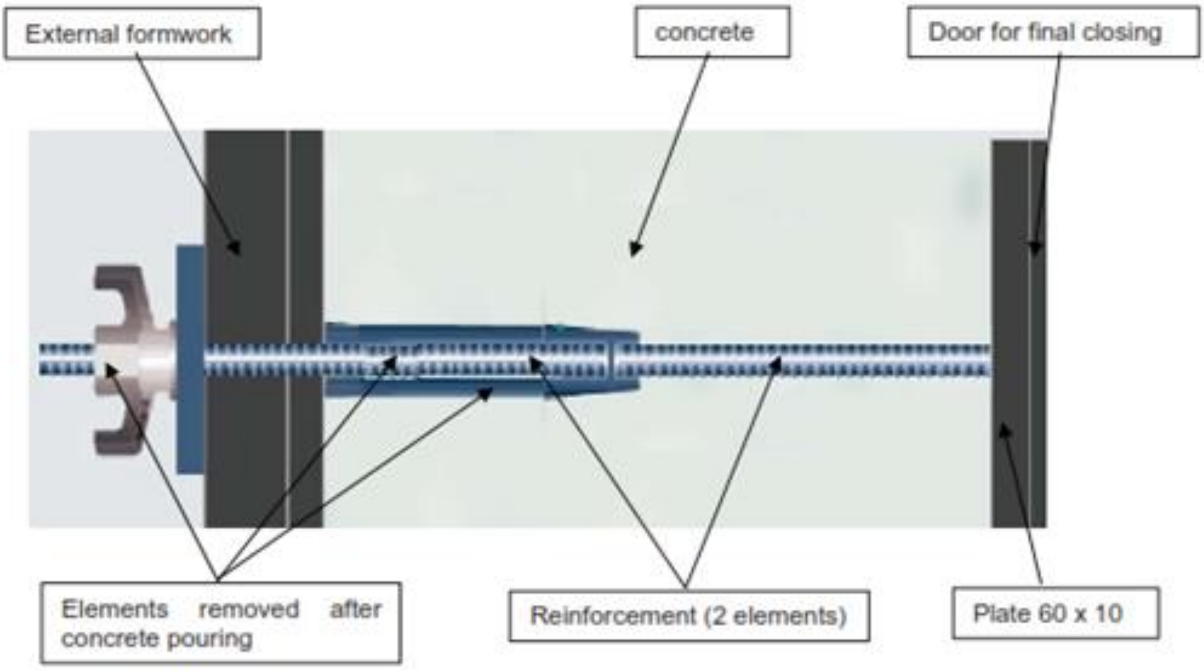


Figure 37 External Formwork, Reinforcement & Concreting

Once the TCOs are sealed and the structural steelwork/concreting completed, the remaining insulation and membrane components will be fitted to the TCO spaces. The membrane panel welding will be within the temporary enclosure and therefore fully isolated from the Detector. All welding will be inspected and cleaned in stages to ensure full continuity with the previously installed membrane tank panels.

Note. If the TCO is decided to be in the top/deck of the cryostat, all previously mentioned procedures must be conducted vertically. In order to accomplish that significant parts of the supporting structure (scaffolding etc.) must remain in place and must be de-assembled and removed in small components through the manhole. This is not impossible, but obviously not even close a safe and efficient proposal.

1.3.2 Decommissioning as Part of Finalization

Once all the remaining insulation and membrane panels have been installed, inspected and cleaned, the temporary enclosures outside and inside the tank will be dismantled. The enclosures and equipment outside the tank will be removed via the construction access tunnels or the service access tunnels. Personnel and all equipment remaining in the tank will exit the tank through the hatch man-ways in the tank deck structure using the monorail hoists and gondolas or stairways attached to the in-tank pump nozzles. From there, the equipment will be removed via the service access tunnels. The hatch man-ways will then be closed and sealed. Figure 38 shows the completed Detector installation with all TCOs and hatch man-ways closed.

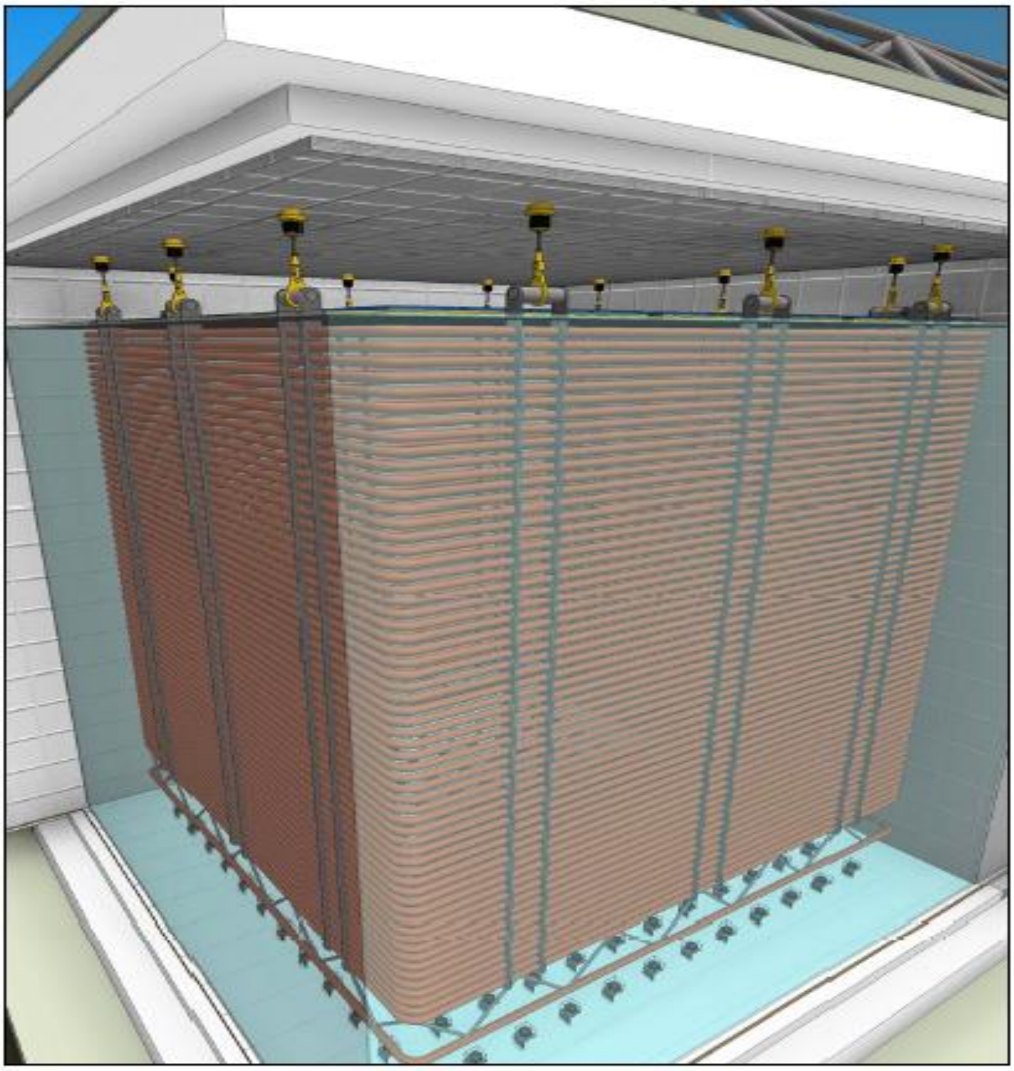


Figure 38 Completed Detector Installation. Courtesy Rockplan Ltd based on Technodyne Ltd design.

2 Construction programme of detector installation

Both the 3 by 1 by 1 (= 3 m^3) prototype detector [Location CERN, B.182] and the 6 by 6 by 6 (= 216 m^3 = 0.3kT) demonstrator [Location CERN, B.887 in the North Area] are planned to be built in advance of the larger 4 times 10kT experiment at Homestake. It is envisaged that valuable information will be gathered from the construction of both the Prototype and Demonstrator experiments that will ultimately benefit both the planning and construction forecasting for the larger experiments later on in the project.

The programmed works are based on the Technodyne 'classic' design for a hanging detector suspended from the tank deck with a Cathode construction of trusses. Any possible savings and detailed planning on a single level slim cathode construction are not taken into account. Any possible additional time requirements, if the access were from the top are also not taken into account.

For comparison the 20kT Lar detector, designed for Pyhäsalmi had a drift surface (roughly the CRP and Cathode area) of 824 m^2 in octagonal shape with a drift length of 20m. The double phase TPC LAr experiment at Homestake has an equivalent area of 12 by 60 = 720 m^2 (for one module of 10+ kT) with a drift length of 13 to 15m (fiducial mass 1 kT / 1m drift, total 13 to 15kT). The construction programme calculated by Rockplan Ltd, Alan Auld Ltd and Rhyal Eng. Ltd can be seen as a conservative approach for the Homestake site, as most of the time is linked with the instrumented surface required and not so much with the drift length, but specific Homestake site related effects and effects of US legal procedure are not taken into account in this construction programme.

Specialist Manufacturers and Fabricators have been approached for details of the supply and fabrication of the component parts forming the Cathode and Field Cage whilst ETH Zurich has provided the design for the Anode. Lead times for delivery have been determined from information supplied by the respective supplier/manufacturer and based on current market conditions. It has to be emphasised that due to the speciality of some component parts of the detector, suitable suppliers/manufacturers are limited in number with even fewer wishing to commit resource to providing specification and cost information necessary to complete the planning of such a project. The Industrial Partners collectively have pooled their present knowledge to deliver a credible programme that demonstrates both the sequence of events necessary to build the double phase TPC LAr detector and the time required to do so according to the scope of design.

The Detector programme has been divided into 3 distinct [and separate] stages, 1) Design, 2) Manufacture/Fabrication and 3) Construction. Where a planner would look to overlap and plan concurrent activities on a programme, to reduce the overall duration, it has not been possible to do this with the detector owing to other activities that influence the various stages. The detector design must be done together with the tank deck design, as the complete detector is suspended from the deck. Fabrication and manufacturing can be started while the tank construction is still on-going. The total time for manufacture / fabrication and construction is calculated to be around 2¾ years for the LAr detector, of which

- 14 months for manufacture/fabrication off-site
- 20 months for construction/installation + testing
- 32 months total works (partially overlap)

LAGUNA-LBNO, LAr 20kT @ PYHÄSALMI	year 5				year 6				year 7				year 8			
-20kT membrane liner + test						X	X	X								
20KT DETECTOR INSTRUMENTATION																
- off site manufacture + fabrication				X	X	X	X	X								
-establishing clean room + CR conditions									X							
- charge read out + top field coils									X	X						
- field coil construction											X	X				
- cathode construction + cleaning												X	X			
- light readout (pmt's)													X			
- electronics + connections testing								X	X	X	X	X	X	X		
- closing of TCO and final cleaning														X		

Figure 39 Summary construction programme for a double phase LAr Detector. Courtesy Rockplan Ltd.

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[i] LAGUNA-LBNO FP7 EC GA 284518; Deliverable 2.2, part Pyhäsalmi, Report on underground tank and underground layout, courtesy Technodyne Ltd, Alan Auld Ltd & Rockplan Ltd (11th May 2013).
[ii] LAGUNA-LBNO FP7 EC GA 284518; Deliverable 2.4: Final Report, feasibility of underground construction, cost and risks: courtesy Rockplan Ltd, Technodyne Ltd, Alan Auld Ltd & Rhyal Eng. Ltd (13th August 2014).
[iii] LAGUNA-LBNO FP7 EC GA 284518; Deliverable 3.1, part Liquid Argon at Pyhäsalmi, Report on detector installation, courtesy Technodyne Ltd, ETH Zürich, Alan Auld Ltd & Rockplan Ltd.(14th June 2014)